INSTRUCTION MANUAL

REGATRON

POWER SUPPLY

MODEL 224A/224AM

SERIAL No. _____

ELECTRONIC MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

TELEPHONE: (201) LIberty 2-0300 TWX: (201) 542-2273 CABLE: ELMEASCO

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REGATRON®
PROGRAMMABLE
POWER SUPPLY

MODEL 224A

SERIAL No. _____

ELECTRONIC
MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

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Eatontown, New Jersey

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REGATRON MODEL 224A

TABLE OF SPECIFICATIONS

OUTPUT
0 to 100 volts
0 to 200 milliamperes

REGULATION
Line—0.15% or 0.05 volts, whichever is greater, for line change from 105 to 125 volts ac, 50-60 cps.
Load—0.1% or 0.05 volts, whichever is greater, no load to full load.

REGULATION WITH CHOPPER-STABILIZATION
(Models 224AK and 224AMK)
Line or Load—0.01% or 0.003 volt, whichever is greater.

STABILITY—Within 0.1% or 50 millivolts, whichever is greater, in 8 hours after 30 minutes warmup, under fixed line, load, and temperature conditions, with precision high stability external programming resistor.

STABILITY WITH CHOPPER STABILIZATION—0.05% + 2 millivolts, same conditions as above.

RIPPLE— 1 millivolt RMS maximum, with positive or negative output grounded.

INTERNAL IMPEDANCE—Less than .01 ohm at low audio frequencies; 0.1 ohm to 10 KC; 1 ohm to 40 KC.

TRANSIENT RESPONSE—For step change from no load to full, or full to no load, output recovers to within dc regulation limits of initial value within 1 millisecond.

OVERVOLTAGE CAPABILITY—See paragraph 2-10.

REMOTE PROGRAMMING RESISTANCE—1,000 ohms per volt of output.

AMBIENT TEMPERATURE RANGE— —20°C to +45°C.

OUTPUT POLARITY—Panel switch for positive or negative ground or floating output.

CIRCUIT PROTECTION—Input ac line fused, dc output fused.

TERMINATIONS—Front: 5-way insulated binding posts. Rear: barrier-type terminal strips. Line cord is 3-conductor type.

CONTROLS—Main control and 10-volt vernier are of wirewound type. Panel calibration is approximate.

MOUNTING—Unit fits 19″ standard racks and is equipped with rubber feet for table mounting. Top and bottom are protected by perforated metal covers.

FINISH—Smooth gray semi-gloss enamel Class 2 per MIL-E-15090.

DIMENSIONS—3½ inches high, 9½ inches deep, 19 inches wide.

WEIGHT—16 pounds approx.

ELECTRONIC MEASUREMENTS COMPANY, INC.
EATONTOWN, NEW JERSEY

#100
9-12-60

INSTRUCTION MANUAL CHANGE

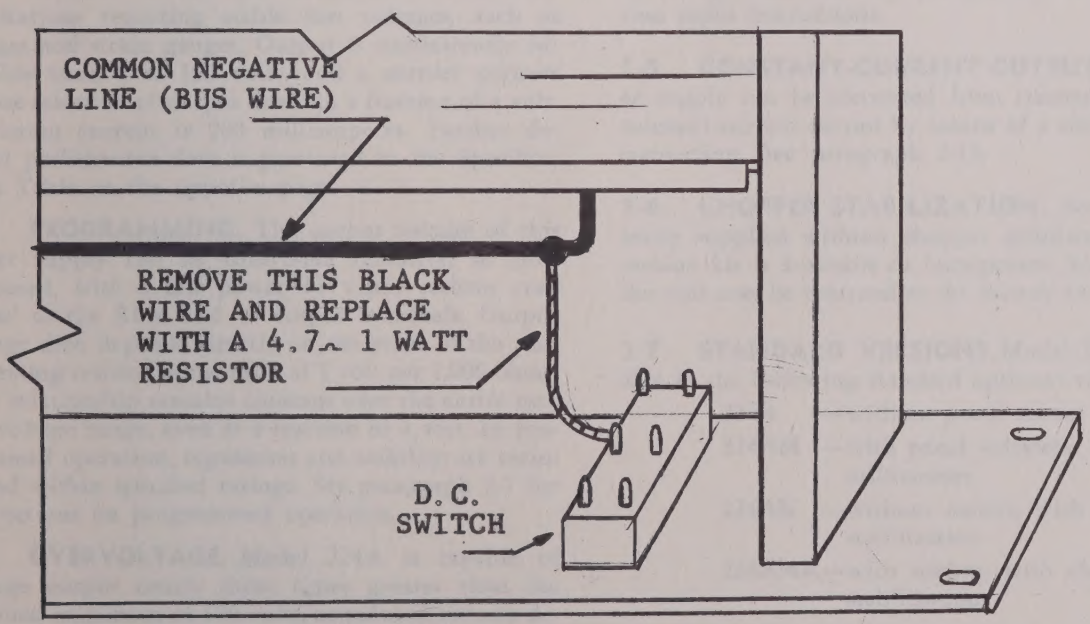
MODELS 212A AND 224A

DC SWITCH MODIFICATION

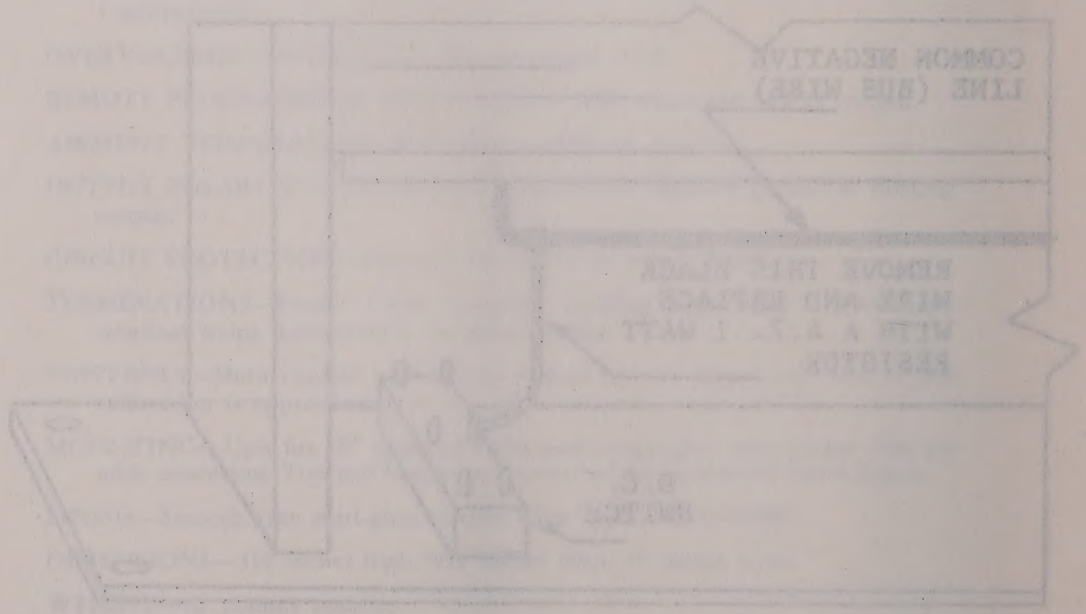
The reliability and life of the DC switch in Models 212A and 224A can be improved by limiting the discharge current which flows through the switch from the output capacitor. This is especially true if a larger than normal output capacitor is installed. The following modification accomplishes such limiting by inserting a 4.7K, 1 watt resistor into the positive line between the center tap of the transformer high voltage secondary and the DC switch, S2. This change is now in effect in present production starting with serial number 5708, and should be incorporated immediately into all units in the field as illustrated and described below:

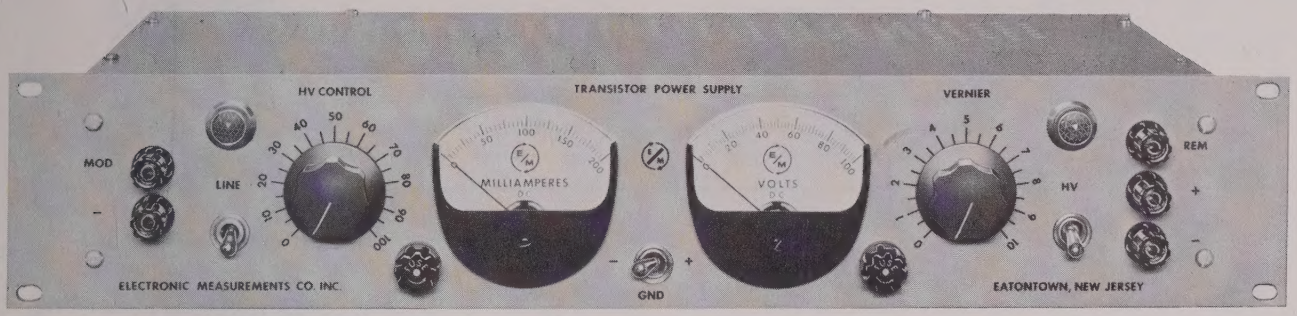
1. Remove black wire running from the common negative line (bus wire along center of chassis) to the center terminal of the D.C. switch (left center as viewed from front of chassis).

2. Replace the wire that was removed with a 4.7 ohm 1 watt resistor. Connect to same points that the wire was removed from.



TOP VIEW
(FRONT RIGHT CORNER)





PART 1 OF THIS MANUAL DESCRIBES THIS POWER SUPPLY.

PART 2 GIVES COMPLETE OPERATING INSTRUCTIONS.

PART 3 DESCRIBES THE CIRCUITRY.

PART 4 COVERS MAINTENANCE.

PART 5 CONTAINS THE PARTS LIST AND SCHEMATIC DIAGRAM.

PART 1
DESCRIPTION

1-1. REGATRON Model 224A Programmable Power Supply is a wide-range source of voltage-regulated d-c power designed for use with transistors and for other applications requiring stable low voltages, such as bridges and strain gauges. Output is continuously adjustable from 0 to 100 volts, and a vernier permits precise selection of output down to a fraction of a volt. Maximum current is 200 milliamperes. Further detailed performance data is presented in the Specifications Table on the opposite page.

1-2. PROGRAMMING. The output voltage of this power supply can be controlled remotely, or programmed, with a low power (1 watt) resistor connected to the REM and + output terminals. Output voltage then depends directly on the value of the programming resistor in the ratio of 1 volt per 1,000 ohms. This relationship remains constant over the entire output voltage range, even at a fraction of a volt. In programmed operation, regulation and stability are maintained within specified ratings. See paragraph 2-7 for instructions on programmed operation.

1-3. OVERVOLTAGE. Model 224A is capable of voltage output nearly three times greater than the specified maximum of 100 volts, at reduced current demands. See paragraph 2-10 for instructions on overvoltage operation.

1-4. MODULATION. Output can be modulated with a signal up to 10 kc in frequency, depending on operating conditions. See paragraph 2-11 for modulation input instructions.

1-5. CONSTANT-CURRENT OUTPUT. This power supply can be converted from constant-voltage to constant-current output by means of a simple external connection. See paragraph 2-15.

1-6. CHOPPER STABILIZATION. For units originally supplied without chopper stabilization, a conversion kit is available to incorporate this feature, or the unit may be returned to the factory for conversion.

1-7. STANDARD VERSIONS. Model 224A is available in the following standard optional versions:

224A —without panel meters
224AM —with panel voltmeter and milliameter
224AK —without meters, with chopper-stabilization
224AMK—with meters, with chopper-stabilization

This instruction manual is applicable to all the above standard versions.

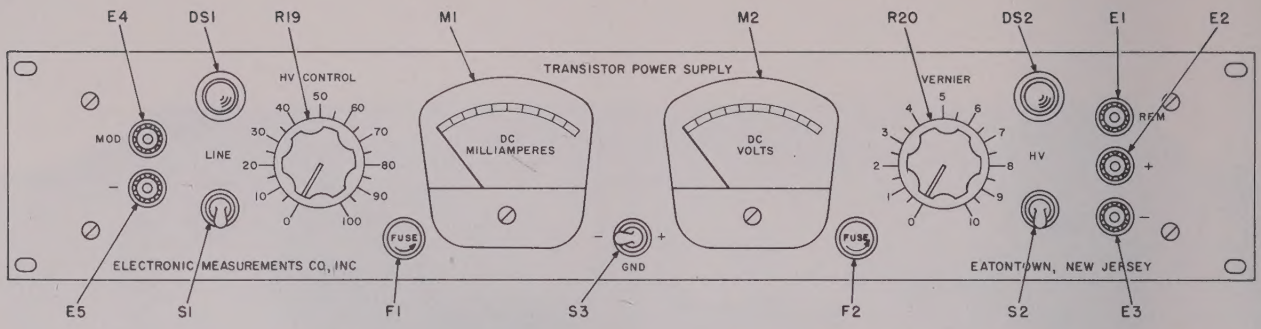


Figure 2-1. Front Panel.

PART 2
OPERATION

2-1. INSTALLATION. This unit operates on 105 to 125 volts, 50 to 60 cycles, single phase ac. Input power required is 132 watts, 191 volt-amperes.

The equipment may be table or rack mounted in a standard 19-inch rack. The rubber mounting feet may be removed from the bottom cover if they interfere with other rack-mounted equipment. Sufficient clearance should be allowed above and below the unit to provide adequate ventilation. The top dust-cover may be removed, if desired, to increase the ventilation.

2-2. CONTROLS AND TERMINATIONS.
See figure 2-1.

a. LINE switch: controls a-c line input.
b. HV switch: controls regulated d-c output.
c. GND switch: permits positive or negative chassis ground or floating output.
d. HV CONTROL: for adjustment of output voltage, calibrated to dial markings on panel.
e. VERNIER: for continuous fine adjustment through 10 volts. VERNIER and HV CONTROL settings are additive.
f. MOD and — terminals: for modulation input. See paragraph 2-11.
g. + and — terminals: for connection of load.
h. REM terminal: with + terminal, for programming resistor connection.
i. NULL adjustment: (on chassis) for zeroing of balanced input detector. See paragraph 4-2.
j. CAL adjustment: (on chassis) for adjustment of output to panel markings or for exact 1,000 ohms per volt programmed operation. See paragraph 4-3.

2-3. FUSES. This unit contains the following fuses mounted on the front panel:

F1—2 amps (at left), in a-c line input circuit
F2—1/4 amp (at right), in + d-c circuit, to protect against short circuit or excess load across output

2-4. PRELIMINARY. Before connecting to ac power, check that:

a. LINE switch is off (down).
b. HV switch is off (down).
c. HV CONTROL and VERNIER are at minimum, fully counter-clockwise.
d. GND switch is at desired condition. Center position provides floating output, the — position ties black lower post to chassis, the + position ties the red + post to chassis.

2-5. LINE AND LOAD CONNECTIONS

a. Connect line cord to ac power outlet.
b. Connect load to + and — output posts. It should be noted that the regulation of this unit is measured at the output posts. To maintain the specified regulation in actual service, the load wires must be heavy enough to prevent substantial voltage drops between the output posts and the load.

2-6. LOCAL OPERATION

a. Throw LINE switch on: green indicator should light.
b. Set HV CONTROL to desired voltage indicated on panel or voltmeter. If greater resolution is desired, this can be a coarse setting. The VERNIER, which is additive, provides the fine setting.

c. Turn VERNIER to precise voltage desired. For an output of 10 volts or less, set HV CONTROL to zero and select output with VERNIER alone to realize greater stability.

d. After one minute, throw HV switch on: red indicator should light. Desired voltage is now applied to load.

NOTE

Always allow a one-minute warmup period from a cold start before throwing HV switch on. This switch, when off, shorts the + and — output posts, thus effectively preventing application of any excess voltages to load during warmup. Subsequently, the HV switch can be thrown on or off with no danger of exceeding the desired output voltage.

2-7. PROGRAMMED OPERATION. As stated in paragraph 1-2, the output of this power supply can be controlled from a remote point, or programmed, with a resistor. For programmed operation, proceed as follows:

a. Throw HV and LINE switches off.

b. Remove the top dust cover.

c. Sever the short jumper between the + and REM posts.

d. Replace the cover.

e. Connect the load and the programming resistor as shown in figure 2-2A. Output voltage depends on programming resistance in the ratio 1:1,000. For example, to obtain 50 volts, use a 50,000 ohm resistor.

f. Throw LINE switch on.

g. Set HV CONTROL and VERNIER to zero.

h. Throw HV switch on. Programmed voltage is now applied to load.

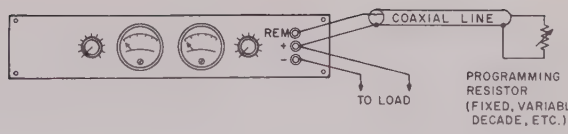
Where both load and programming resistor are at a distance from the power supply, but close to each other, a common + lead may be employed, as in figure 2-2B. This arrangement yields remote sensing for regulation directly at the load by eliminating the effect of voltage drop in the + lead.

To restore the unit to local operation, throw HV and LINE switches off, remove programming resistor connection, re-connect internal jumper between + and REM posts, and follow the procedure in paragraph 2-6.

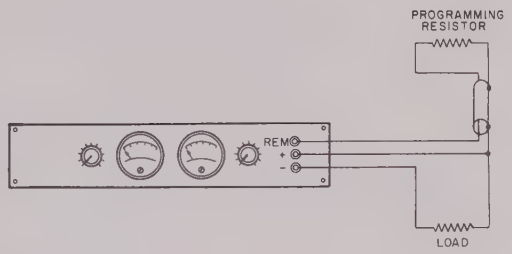
2-8. The following considerations apply to programmed operation:

a. Unless the programming resistor itself is physically shunted across the REM and + terminal posts, it is desirable to use shielded or coaxial cable, as shown in figure 2-2A, to prevent injection of ripple and noise from external sources. An insulated cable such as RG 58/U is recommended because of the fact that the coaxial sheath carries output potential.

b. For long-term or permanent programmed operation it is advisable to short out the internal controls. This will eliminate possible disturbance of programmed voltage by accidental rotation or vibration of the HV CONTROL or VERNIER, and will yield, in general, greater stability.



A. Programmed Operation.



B. Programmed Operation with Remote Sensing.

Figure 2-2. Internal jumper must be cut for programmed operation.

Programmed operation can be combined with use of the internal controls, when convenient or necessary, merely by disregarding step g. of paragraph 2-7. In this case the value of the programming resistor will be added to the values to which the internal controls are adjusted, and the total resistance will determine output voltage.

2-9. PROGRAMMING SUGGESTIONS. Although the above programming instructions are illustrated with a single, fixed resistor as the remote control, it is evident that variable resistors, driven potentiometers, or fixed resistors wired to stepping switches can be employed to deliver voltages in a wide variety of time/amplitude patterns.

The time required for switching from one programmed voltage to another varies from the seconds range to the milliseconds range, depending upon conditions. Modifications for special switching times are available on special order from the factory.

It is also evident that programming can be manually or automatically actuated. As an example of automatic programming, figure 2-3 illustrates a four-level rotary stepper switch, each level of which controls one Regatron supply. As shown, the entire battery can be stepped through a sequence of four programmed outputs upon command.

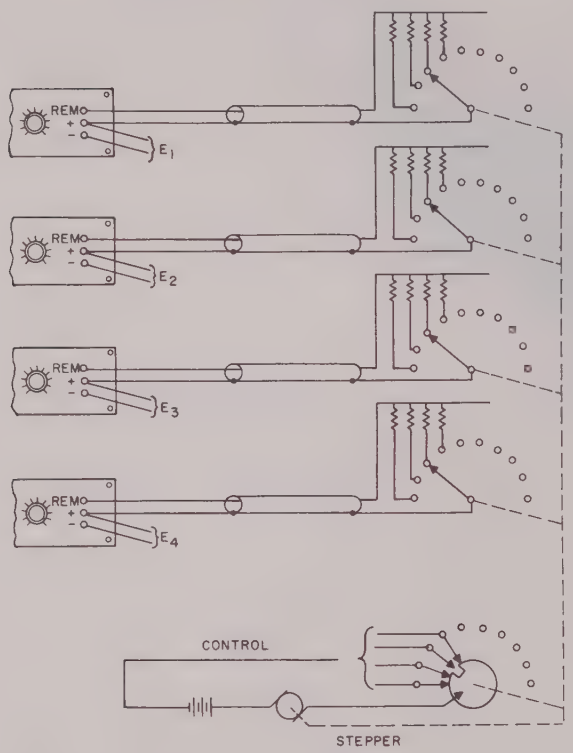


Figure 2-3. Programming with Stepper Switch. Each level controls one Regatron power supply.

In an extensive system, a central board may contain the switches or rheostats for the programming of several Regatron power supplies in different locations. In such a system it is practical to calibrate the control elements directly to dial markings, remembering that the accuracy of calibration depends upon the accuracy of the resistances and/or the dial markings.

2-10. OVERVOLTAGE OPERATION. For overvoltage, an external programming resistor must be employed to substitute for or add to the resistance of the HV CONTROL and VERNIER in order to extend the control resistance range and, therefore, the output range. Figure 2-4 gives the current derating of this unit in overvoltage operation. For example, at 250 volts, current is available up to about 30 ma. This voltage output could be obtained by setting the HV CONTROL and VERNIER to zero, and shunting a 250,000 ohm resistor across the REM and + posts. Alternatively, the controls could be set for 100 volts, with an external 150,000 ohm resistor across the REM and + posts.

2-11. MODULATION. The output of this unit can be modulated by a dc or ac voltage injected via the MOD terminal posts.

DC Offset—A dc offset to a maximum of ± 4 volts can be applied to the MOD input. Transfer gain is 0.9 approx.

AC Signal—Maximum frequency of ac modulation depends upon operating conditions. With no load, best results are obtained with modulation frequencies not exceeding 400 cycles. With a 30 ma load, the time constant across the output permits modulation to 10 kc; when the useful load does not draw the full 30 ma an auxiliary load can be placed in shunt to draw the remainder. It should also be noted that the percentage of modulation at outputs under 10 volts is limited by high ac current flow. For example, a 10 ohm load draws the nominal current maximum of 200 ma at 2 volts output. In such a case, ac modulation could cause the current capability of the power supply to be exceeded and result in a malfunction.

2-12. One side of the MOD input is returned to the negative of output voltage. A grounded modulation input should therefore be used with the GND switch at the — position, since the + position would place one side of the signal source below ground at the potential to which the output of the power supply has been adjusted. If it is desired to use a grounded modulation input with the GND switch at the + position, place a capacitor and 1,000 ohm resistor in series with the MOD input connection; the capacitor should be large enough to pass the lowest desired modulating frequency. A floating modulation input should be used with the GND switch at the + position.

2-13. SMALL SIGNAL MEASUREMENTS. One method for the measurement of transistor parameters requires the superposition of a small ac signal on one of the dc potentials. This unit is particularly suitable for this since the dc voltage may be set independently, and modulation then introduced to provide the required small signal, subject to the instructions given above.

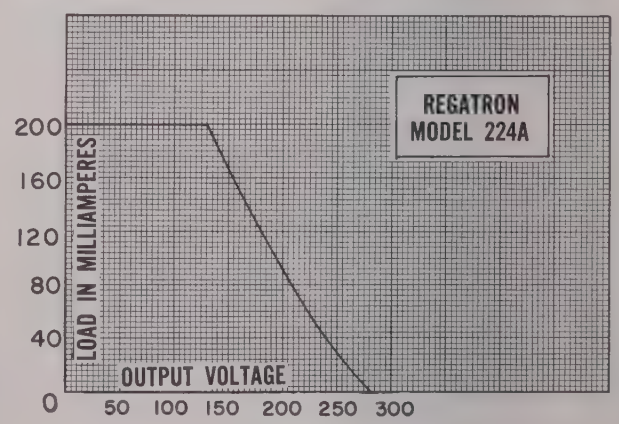


Figure 2-4. Overvoltage operation, showing current deratings.

2-14. OSCILLATION. To make modulation possible the output system of this unit has been made relatively "soft". Because of this, some sensitivity to the type of load is present, and a capacitor of .1 microfarad directly across the output may cause high frequency oscillation. To eliminate this sensitivity, a capacitor of about 20 uf may be connected directly across the output. This, of course, disables the modulation feature except at very low frequencies.

2-15. CONVERSION TO CONSTANT-CURRENT. For conversion from constant-voltage to constant-current output, proceed as follows:

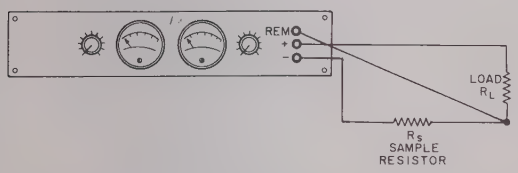


Figure 2-5. Conversion to constant-current operation.

a. Select a sample resistor, R_S in Figure 2-5 below, which will carry the load current and develop a sample voltage for the control system. To determine its value, select a sample voltage. Five to 10 volts is a good range. Although the voltage may be made as high as desired it must be remembered that the sample voltage subtracts from the available output voltage. If E_S is the sample voltage and I_L is the desired load current, then $R_S = \frac{E_S}{I_L}$, where R_S is in ohms and I_L is in amperes. The actual wattage will be $E_S \times I_L$. The resistor used should have a somewhat higher wattage rating.

b. Make connections as shown in Figure 2-5 and set both panel controls to zero.

c. Remove the top cover and sever the short jumper between the REM and + terminal posts. Then replace cover.

d. Throw the LINE switch on.

e. Bring current up to the desired value by turning the VERNIER up to the voltage selected as the sample in step a. above. In constant-current operation the VERNIER is the output control (for sample voltages up to 10 volts).

The conversion described above provides good dc regulation. The ac impedance of the power supply, however, is relatively low, and this should be noted in considering applications. Where output impedance is unimportant, ripple can be reduced somewhat further by connecting a capacitor across the load of between 0.1 and several microfarads.

2-16. CHOPPER STABILIZED OPERATION. As stated in the specifications table, this unit achieves regulation of 0.01% or 3 mv, and stability of 0.05% + 2 mv for 8-hours when equipped with chopper stabilization. Although both ratings are conservative, note that the stability figure is specified with the unit in programmed operation, using an external resistor of high electrical and (in the case of a variable resistor) high mechanical stability. This rating can be realized only in such operation, and with the internal controls shorted out or set to zero to prevent them from contributing variations resulting from accidental rotation or vibration.

PART 3
CIRCUITRY

Note: Circuit references are made to the schematic diagram, except where indicated.

3-1. GENERAL. This power supply employs a full-wave rectifier, the positive output of which is applied to series amplifiers controlled by the regulator loop. The resulting regulated dc voltage constitutes the output.

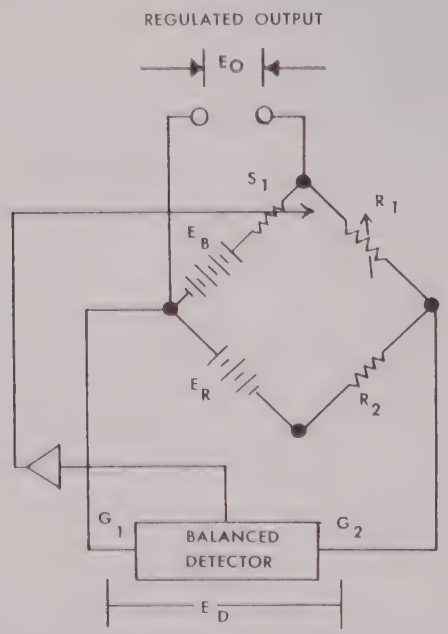


Figure 3-1. Output control configuration.

3-2. CONTROL SYSTEM, LOCAL AND PROGRAMMED. Figure 3-1 illustrates the output control configuration in simplified form. If inputs G_1 and G_2 are equal ($E_D = 0$) then:

$$\frac{E_0}{E_R} = \frac{R_1}{R_2} \text{ and } E_0 = E_R \times \frac{R_1}{R_2}$$

where E_0 = regulated output voltage
E_R = internal reference voltage
and R_2 is a fixed resistor.

Since E_R and R_2 are constant, $E_0 = KR_1$; or, the output voltage is dependent only upon the value of R_1 which, in local operation of the power supply, consists of the HV CONTROL and VERNIER. In programmed operation, R_1 is the remote programming resistor. In either local or programmed operation, the voltage output = $0.001R_1$, or, 1,000 ohms control resistance per volt of output.

In practice, R_2 can be adjusted with the CAL control (on the chassis) for exact 1,000 ohms-per-volt programmed operation, or to calibrate output with panel dial markings.

3-3. REGULATOR SYSTEM, GENERAL. The regulator system employs a balanced input detector, V7, connected from the zero point of the input bleeder to the negative reference point (minus) to detect departures from balance. The amplifier error is applied to a high gain amplifier, V4, which drives the grids of the series amplifiers V8 and V9 in such a manner as to overcome the error. Because of the high gain of the system the error at equilibrium is very small. A gas tube, V3, maintains a very stable reference potential, and v/r tubes V1 and V2 maintain steady service potentials for the regulator tubes.

3-4. UNREGULATED DC SUPPLY. The main dc supply employs four Type F6 diodes CR1, 2, 3, 4 for full-wave rectification, with filtering provided by a 120 UF electrolytic capacitor, C1. This is the source of voltage for the output and for the plates of V7. A 150 volt negative supply is also derived from a series of selenium rectifiers CR5, 6, 7, and filtered by an 80 UF capacitor, C2.

3-5. REFERENCE. The internal reference, also employed for the cathode of V4, is a gas-filled 85A2, V3, which yields a stable voltage of approximately —85 volts. A stable —150 volts is obtained across an 0A2, V2, and +108 volts across an 0B2, V1.

3-6. SERIES AMPLIFIERS. Paralleled 6550 beam power pentodes, V8 and V9, are employed as series amplifiers. These act as variable conductances. Positive output is obtained from the cathodes; control grids are direct-coupled to the plate of the starved amplifier V4. With the HV switch open, the plates of V8 and V9 are removed from + high voltage. Resistor R7 absorbs stray electron flow through V8 and V9 at cutoff when no load is connected, thus preventing buildup of potential at the output terminals and consequent loss of control.

3-7. BALANCED INPUT DETECTOR. A 12AX7 cathode-coupled amplifier V7 is employed as a balanced input detector, grid 2 of which is effectively at the positive of the reference potential, and grid 7 at the other null point on the opposite side of the control bridge. Plate supply is taken from V1, and cathodes are returned through R11 to V2. The NULL control R15 permits setting of the balanced input detector to zero difference between grids. Output from plate 1 is applied across a coupling and voltage divider network consisting of EM10 glow discharge regulator tubes V5 and V6 and resistors R8 and R10. The glow tubes couple plate potential to the grid of V4, maintaining a

constant voltage drop which permits the grid to follow the potential at the plate of V7, and thus constituting an effective dc coupling which avoids any substantial loss of gain.

3-8. DRIVER AMPLIFIER. This stage employs a 6AU6 pentode in high gain, low current operation. Output from V4 is direct-coupled to the grids of the series tubes, V8 and V9.

3-9. CHOPPER STABILIZATION. On units so equipped, the chopper stabilizer is installed across the grids of the direct-coupled balanced input detector. Without chopper stabilization, this stage is subject to zero offset, with the result that output voltage may drift up to .1% or 50 millivolts for 8-hours. The chopper unit, utilizing a contact modulator (chopper), continually samples the offset at grid 7 of V7, chops it to produce a square wave, amplifies, rectifies, and filters it, and applies the resulting correction signal via reference grid 7 to the regulator system to reduce the net offset to a vanishingly small value. The chopper-stabilizer adds a gain of approximately 1000 to the regulator system. Both regulation and stability improve as given in the Specifications Table.

3-10. MOD AND OUTPUT CIRCUITRY. The MOD input is applied through R12, a parasitic suppressor, to reference grid 2 of the balanced input detector V7; the MOD – terminal is returned to negative.

This power supply is supplied with a short jumper connected internally between the REM and + terminals for local operation. Severing this jumper permits the use of an external programming resistor in series with the internal controls.

Resistor R21 and capacitor C8 adjust the feedback loop characteristic for stable operation. Capacitor C7 feeds ac signals directly to the input grid of V7. In addition, a semiconductor F6 diode, CR8, is connected across the output to present a low impedance to reverse voltages which may occur when the unit is shut off, and thus to protect the external load.

PART 4
MAINTENANCE

Attention is called to the Warranty under which this equipment is sold, to be found opposite the Table of Contents page at the front of this book.

4-1. PARTS REPLACEMENT. An electrical parts list accompanies the schematic diagram in Part 5 of this book, and, along with the parts location illustrations, will identify all parts to be replaced. In general, replacement parts are completely defined by the values and tolerances indicated on the parts list. The following components, however, require special attention:

a. V1, V2 and V7—Replacement of any of these tubes will affect null balance, which should therefore be readjusted as per paragraph 4-2.

b. V3—Replacement of the 85A2 will change the internal reference voltage somewhat, and necessitate recalibration as per paragraph 4-3. If the replacement 85A2 does not yield approximately correct calibration, or proves unstable, a satisfactory tube will be furnished by the factory upon request.

c. HV VOLTAGE and VERNIER controls—If either of these wirewound potentiometers is defective, it is advisable to obtain an exact replacement. If none is available locally, an order should be addressed to the factory. Any temporary substitute potentiometer should provide an arc of 280° effective rotation for the panel dial markings to represent output correctly.

d. V8 and V9—Because of large mu variations among 6550 tubes, some replacements will not permit control, particularly at higher line voltages. Some selection of 6550 replacements may occasionally be necessary. See paragraph 4-9.

4-2. NULL ADJUSTMENT. The NULL control, found on the chassis, permits adjustment of the balanced input detector to null, or zero level. This adjustment, which holds over the entire operating range, is made as follows:

a. Remove the top cover.

b. With the HV CONTROL and VERNIER at zero, throw the LINE switch on. After a minute (from cold start) throw the HV switch on.

c. Connect a voltmeter across the output + and — posts. Use 3 volt dc scale or lower.

d. Adjust the NULL control for zero on the meter. A very sensitive indication can be obtained by alternately connecting and disconnecting the meter lead.

4-3. CALIBRATION. The CAL control, also found on the chassis, requires adjustment for any one of three reasons:

for close agreement between panel markings and output, or

for exact 1,000 ohms-per-volt ratio in programmed output, or

for recalibration to either of the above after replacement of V3.

This adjustment can be performed in either of two ways: with an accurate voltmeter or with an external, precise source of voltage.

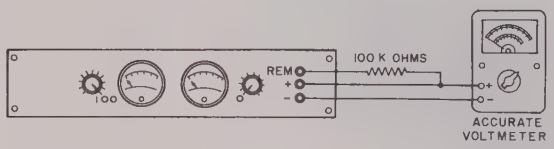


Figure 4-1A. Calibration—With Accurate Voltmeter for exact 1000 ohms-per-volt programming.

4-4. If an accurate voltmeter is employed, proceed as follows, referring to figure 4-1A.

a. Remove top cover. Connect meter across + and — output terminals.

b. To calibrate panel markings, turn VERNIER to zero and the HV CONTROL to 100. Throw LINE, then HV switches on, and adjust CAL control (on chassis) for a 100 volt reading on the external voltmeter.

c. To calibrate for exact 1000 ohms-per-volt programmed output, turn VERNIER and HV CONTROL to zero. Set up for programming and connect a 100,000 ohm resistor across the REM and + terminals. Throw LINE, then HV switches on, and adjust CAL control for 100 volts on the external voltmeter.

4-5. If an external, precise source of voltage is employed, proceed as follows, referring to figure 4-1B.

a. Connect the negative outputs of the unit and the external voltage source together.

b. Connect an accurate voltmeter between the positive terminals of the Regatron unit and the external source.

c. Set the external source to exactly 100 volts.

d. To calibrate panel markings, turn VERNIER to zero and the HV CONTROL to 100. Throw LINE, then HV switches on, and adjust CAL control for a zero reading on the external voltmeter. Use the lowest dc meter range available.

e. To calibrate for exact 1000 ohms-per-volt programmed output, turn VERNIER and HV CONTROL to zero. Set up for programming and connect a 100,000 ohm resistor across REM and + terminals. Throw LINE, then HV switches on, and adjust CAL control for zero on the external meter.

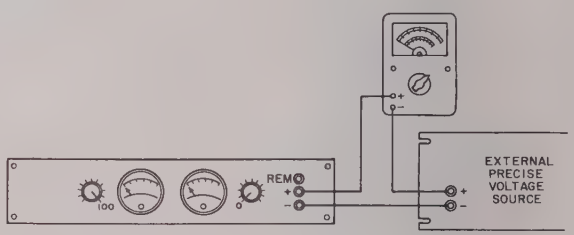


Figure 4-1B. Calibration — With External, Precise Voltage Source.

4-6. TABLE OF RESISTANCES. Conditions of measurement:

a. A-c line cord not connected to power.
b. No load connected.
c. LINE and HV switches off. GND switch at –.
d. HV CONTROL at 0. VERNIER at 0.
e. Readings from indicated tube pins to B- post.

RESISTANCES

TUBE	PIN								
	1	2	3	4	5	6	7	8	9
V1	—	—	—	—	∞	—	0		
V2	0	50K	—	50K	0	—	50K		
V3	0	50K	—	—	0	—	50K		
V4	1 meg	68K	0	0	∞	180K	68K		
V5	At pin 1 of V7: ∞. At junction V5-V6: ∞.								
V6	At junction V6-R8: 1 meg.								
V7	∞	1200	210K	0	0	∞	100K	220K	0
V8	—	0	∞	∞	∞	0	0	0	
V9	—	0	∞	∞	∞	0	0	0	
At junction CR2-CR4: at least 500K.									

4-7. TABLE OF VOLTAGES. Conditions of measurement:

a. Line input 115 volts ac. LINE and HV switches on.
b. HV CONTROL at 90, VERNIER at 10.
c. No load connected.
d. GND switch at –.
e. Readings from indicated tube pin to — post.

VOLTAGES

All voltages are dc unless noted.

TUBE	PIN								
	1	2	3	4	5	6	7	8	9
V1	108	—	—	—	108	—	0		
V2	0	—150	—	—150	0	—	—150		
V3	0	—85*	—	—85*	0	—	—85*		
V4	—85*	—85*	6.3 AC	6.3 AC	65	—51	—85*		
V5	At pin 1 of V7: 41. At junction V5-V6: —18.								
V6	At junction V6-R8: —78.								
V7	41	0	0	6.3 AC	6.3 AC	108	0	0	0
V8	—	6.3 AC	330	330	65	103†	0	103	
V9	—	6.3 AC	330	330	65	103†	0	103	

*Approximate. Values range from 83 to 87 volts.
†Tie point only.

4-8. TROUBLE-SHOOTING TABLE. Referenced below are several possible symptoms of troubles which can develop, with their most likely causes, and remedies. This table is intended to serve as a brief guide in trouble shooting Model 224A.

SYMPTOM	CAUSE	REMEDY
1. Unit is dead when LINE switch is thrown on.	a. Fuse F1 blown. b. Fuse F1 open, defective.	a. Replace with 2 amp fuse. b. Check F1 for continuity and replace if necessary.
2. Fuse F1 blows repeatedly.	a. Type F6 rectifiers shorted. b. 8J1 diodes CR5, CR6, or CR7 shorted.	a. Replace b. Replace
3. DC fuse F2 blows, output to zero.	a. Short circut load. b. Overload, above 200 ma. c. Fuse F2 open, defective. d. HV CONTROL or VERNIER potentiometer open, with load connected.	a. Check load. b. Check load. c. Check F2 for continuity and replace if necessary. d. Check R19, R20 for resistance. See paragraph 4-1.
4. No control of output, voltmeter pins at top of scale.	a. 6550 series amplifier V8 or V9 shorted. b. 6AU6 amplifier V4 inoperative. c. 0A2 v/r tube V2 open. d. 85A2 reference tube V3 open.	a. Replace. See paragraph 4-1. b. Replace c. Replace d. Replace. See paragraph 4-1.
5. No control of output, voltmeter at zero, fuse F2 not blown.	a. 6550 series amplifier V8 or V9 defective b. F6 diode CR8 shorted (across output terminals) c. 0B2 v/r tube V1 open d. 12AX7 balanced input detector V7 defective	a. Replace. See paragraph 4-1. b. Replace c. Replace d. Replace
6. Voltmeter indication disagrees with control settings at full scale.		a. Re-calibration necessary.
7. Meter reads lower than controls but recalibration impossible or out of CAL range.	a. 85A2 reference tube V3 shifted voltage. b. 0A2 defective.	a. Replace. See paragraph 4-1. Re-calibrate. b. Replace
8. Poor line regulation	a. Defective V1, V2, V3, or V7.	a. Replace. See paragraph 4-1.
9. Poor load regulation	a. Poor load connections b. 6550 series amplifier V8 or V9 defective c. Defective V1, V2, or V3	a. Check external load connections. b. Replace. See paragraph 4-9. c. Replace. See paragraph 4-1.
10. NULL adjustment impossible	a. Fuse F2 blown b. Defective V1, V2, V3, V5, V6, or V7.	a. Replace b. Replace
11. High ripple	a. Defective V2, V3 or V7 b. Defective C1 or C2	a. Replace b. Replace.
12. Oscillation	a. See paragraph 2-14	

4-9. SERIES TUBE FAULTS. In selecting replacement 6550 series tubes, or when a malfunction appears to result from a faulty series tube, the following procedure is recommended:

a. Remove one series tube.

b. Turn the unit on (paragraph 2-6) and apply a load of 100 ma at 100 volts. Check ripple and regulation.

c. Remove the first series tube and repeat with the other tube in the second socket.

d. If a test yields a faulty result, repeat it with a tube known to be good.

e. If a favorable result is obtained, it may be assumed that the previous tube is faulty. If this proves wrong, check for faults in the associated circuits.

4-10. NULL ADJUSTMENT FOR CHOPPER-STABILIZED UNITS.

a. With unit set for zero output connect a 100 millivolt meter across the output + and — terminals.

b. Rotate the NULL control to maximum in one direction and read the output in millivolts. Rotate NULL control to maximum in the opposite direction and read the output in millivolts. The difference between the two extremes should be less than 3 millivolts.

c. Rotate control to approximate center of range. When adjusted as described above the zero offset of the power supply should not exceed 1 millivolt. Usually, if this occurs, it is due to excessive grid current in the 12AY7. The tube should be changed and one used providing less than the specified offset.

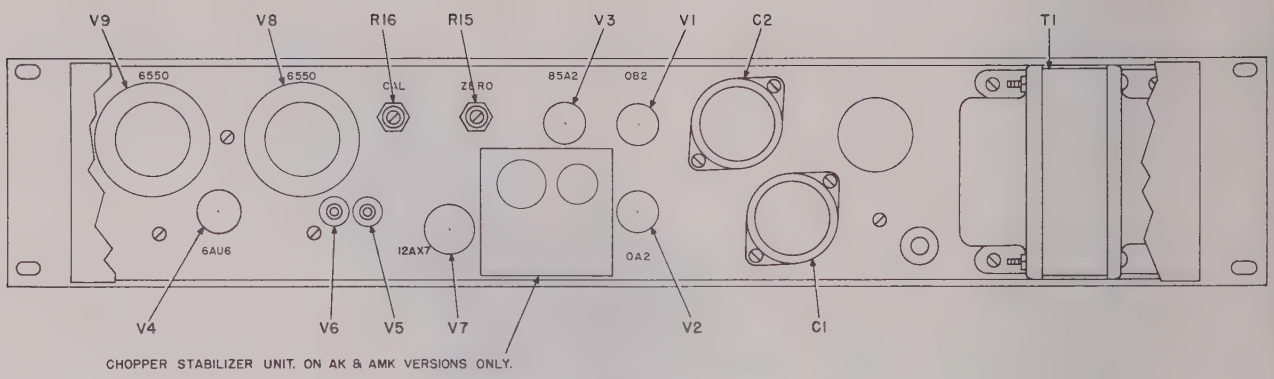


Figure 5-1. Parts Locations.

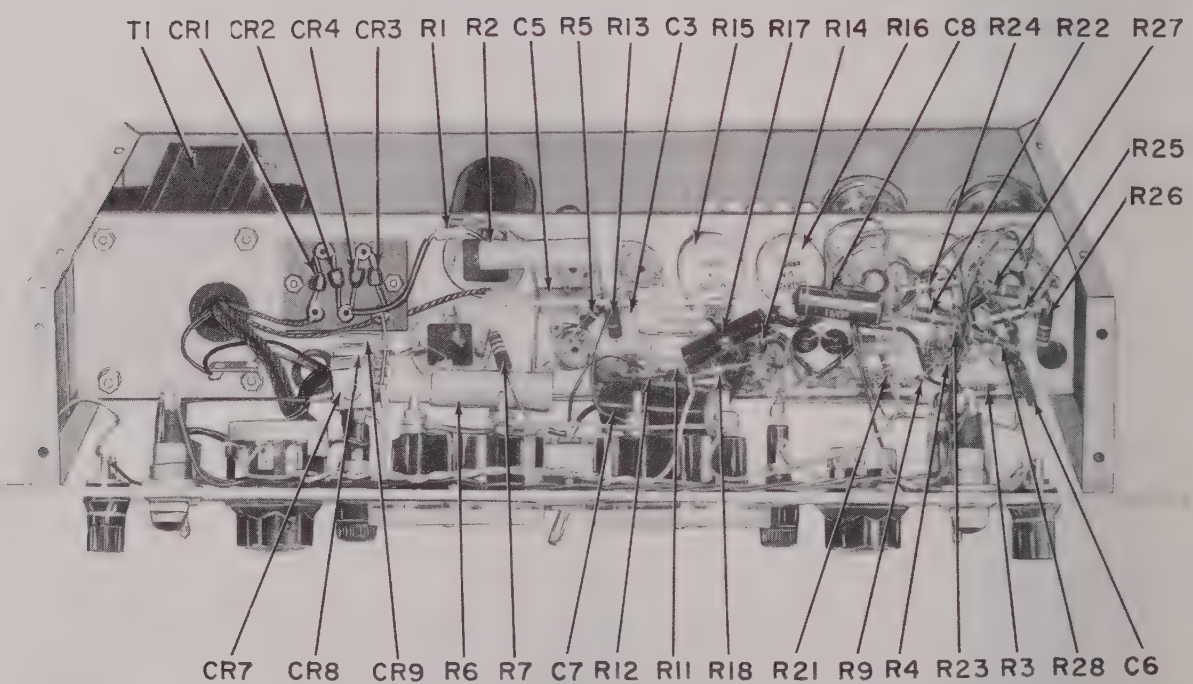


Figure 5-2. Parts Locations.

PARTS LIST

MODEL 224A/AK
PROGRAMMING CONSTANT
1000 ohms-per-volt
115 volts, 50-60 cps input

Revised 2-63

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
*C1	Capacitor, electrolytic, 120uf, 450 VDC, insul. sleeve	D32346	Sprague
*C2	Capacitor, electrolytic, 80uf, 450 VDC, insul. sleeve	D15911	Sprague
C3	Capacitor, mica, 2200uuf ±5%, 500 VDC	CM30B222J	Micamold
C4	Capacitor, mica, 220uuf ±5%, 500 VDC	CM20B221J	Micamold
C5	Capacitor, mica, 2200uuf ±5%, 500 VDC (224A)	CM30B222J	Micamold
C6	Capacitor, mica, 27uuf ±5%, 500 VDC	CM19B270J	Arco
C7	Capacitor, mylar, 0.5uf +20% -10%, 400 VDC	Type 2110-BM	Chicago Cond.
C8	Capacitor, molded, 0.1uf ±20%, 400 VDC	IMP4-P1	Pyramid
CORD	Line cord, 7' lg., #18 gauge, 3 cond., 3 prong plug	346-B-52	EMC
*CR1-4,8	Rectifier, silicon	CER71	Solitron
*CR5,6,7	Rectifier, selenium	8J1	Radio Recepter
*DS1,2	Lamp, 6.3V, 0.25A	44	G.E.
E1,2	Post, binding, red	29-3R	Grayhill
E3,4,5	Post, binding, black	29-3B	Grayhill
*F1	Fuse, cartridge, 2A	3AG2	Sightmaster
*F2	Fuse, cartridge, ½A	3AG½	Sightmaster
J1	Socket, octal (224AK)	9751-9	Eby
M1	Milliammeter, 0-200 MADC ±2% full scale	MM2/MA200	EMC
M2	Voltmeter, 0-100 VDC ±2% full scale	MM2/V100	EMC
R1	Resistor, fixed, WW, vitreous enamel, 5 ±5%, 3W	3X5	Ward Leonard
R2	Resistor, fixed, WW, ceramic, 11K ±5%, 10W	10KT11K	Sprague
R3	Resistor, fixed, comp., 390K ±10%, ½W	EB-3941	Allen-Bradley
R4	Resistor, fixed, comp., 330K ±10%, ½W	EB-3341	Allen-Bradley
R5	Resistor, fixed, comp., 12K ±5%, 1W	GB-1235	Allen-Bradley
R6	Resistor, fixed, WW, ceramic, 7000 ±5%, 10W	10KT7K	Sprague
R7	Resistor, fixed, comp., 270K ±5%, 1W	GB-2745	Allen-Bradley
R8,18	Resistor, fixed, comp., 120K ±10%, ½W	EB-1241	Allen-Bradley
R9	Resistor, fixed, comp., 100K ±10%, ½W	EB-1041	Allen-Bradley
R10	Resistor, fixed, comp., 820K ±10%, ½W	EB-8241	Allen-Bradley
R11	Resistor, fixed, comp., 150K ±5%, 1W	GB-1545	Allen-Bradley
R12	Resistor, fixed, comp., 100 ±10%, ½W	EB-1011	Allen-Bradley
R13	Resistor, fixed, comp., 1200 ±10%, 1W (224A)	GB-1221	Allen-Bradley
R14	Resistor, fixed, comp., 220K ±10%, ½W	EB-2241	Allen-Bradley
*R15	Resistor, variable, WW, 1000 ±5%, 2W, linear taper, 1/4 in. dia.,by 1/8 in. lg. slotted shaft, Series 43	CM18922	Clarostat
*R16	Resistor, variable, WW, 10K ±5%, 2W, linear taper, 1/4 in. dia. by 1/8 in. lg. slotted shaft, Series 43	CM18924	Clarostat
*R17	Resistor, fixed, WW, 80K ±1%, 3W	P3-W	Prec. Resistor
*R19	Resistor, variable, WW, 100K ±5%, 4W, linear taper, 1/4 in. dia. by 1/2 in. lg. shaft Series 10	CM18927	Clarostat
*R20	Resistor, variable, WW, 10K ±5%, 2W, linear taper, 1/4 in. dia. by 1/2 in. lg. shaft, Series 43	CM21189	Clarostat
R21	Resistor, fixed, comp., 27 ±10%, ½W	EB-2701	Allen-Bradley
R22,25	Resistor, fixed, comp., 82 ±10%, 1W	GB-8201	Allen-Bradley
R23,26	Resistor, fixed, comp., 470 ±10%, 1W	GB-4711	Allen-Bradley
R24,27	Resistor, fixed, comp., 47 ±10%, 1W	GB-4701	Allen-Bradley
R28	Resistor, fixed, comp., 4.7 megohms ±10%, ½W	EB-4751	Allen-Bradley
*S1	Switch, toggle, SPST	160-73	Carling
*S2	Switch, toggle, DPDT	2GL53-73	Carling
*S3	Switch, toggle, SPDT (center position "OFF")	2FC63-63	Carling
T1	Transformer, filament and power	5037	EMC
T2	Transformer, filament (224AK)	P-6465	Stancor
*V1	Electron tube	0B2	RCA
*V2	Electron tube	0A2	RCA
*V3	Electron tube	85A2/0G3	Amperex

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
*V4	Electron tube	6AU6	RCA
*V5,6	Electron tube, neon	EM10	EMC
*V7	Electron tube (224A)	12AX7	RCA
*V7	Electron tube (224AK)	12AY7	G.E.
*V8,9	Electron tube	6550 or KT-88	Tung-Sol British Ind.
XDS1	Holder assembly, pilot lamp, green faceted lens	100	Drake
XDS2	Holder assembly, pilot lamp, red faceted lens	100	Drake
XF1,2	Extractor post, fuse, miniature	342003	Littelfuse

PARTS LIST

CHOPPER STABILIZER UNIT
336-A-32

C1	Capacitor, mica, 27uuf ±5%, 500 VDC	CM19B270J	Arco
C2,3,4	Capacitor, mylar, 0.022uf ±10%, 200 VDC	107C223K	Pyramid
*C5	Capacitor, tantalum, etched foil, non-polarized, 20uf ±20%, 25 VDC	TAE20-25SDLK-NP	I.E.I.**
*K1	Chopper, SPDT, 6.3V, 60 cps	Model 175	Airpax
P1	Plug, octal	86-CP8	Amphenol
R1	Resistor, fixed, comp., 120K ±10%, ½W	EB-1241	Allen-Bradley
R2	Resistor, fixed, comp., 33K ±10%, ½W	EB-3331	Allen-Bradley
R3,6	Resistor, fixed, comp., 4.7 megohms ±10%, ½W	EB-4751	Allen-Bradley
R4	Resistor, fixed, comp., 100K ±10%, ½W	EB-1041	Allen-Bradley
R5,7	Resistor, fixed, comp., 680K ±10%, ½W	EB-6841	Allen-Bradley
R8	Resistor, fixed, comp., 56K ±10%, ½W	EB-5631	Allen-Bradley
R9	Resistor, fixed, comp., 270K ±10%, ½W	EB-2741	Allen-Bradley
R10	Resistor, fixed, comp., 1 megohm ±10%, ½W	EB-1051	Allen-Bradley
*V1	Electron tube	12AX7	RCA

** International Electronic Industries, Inc.

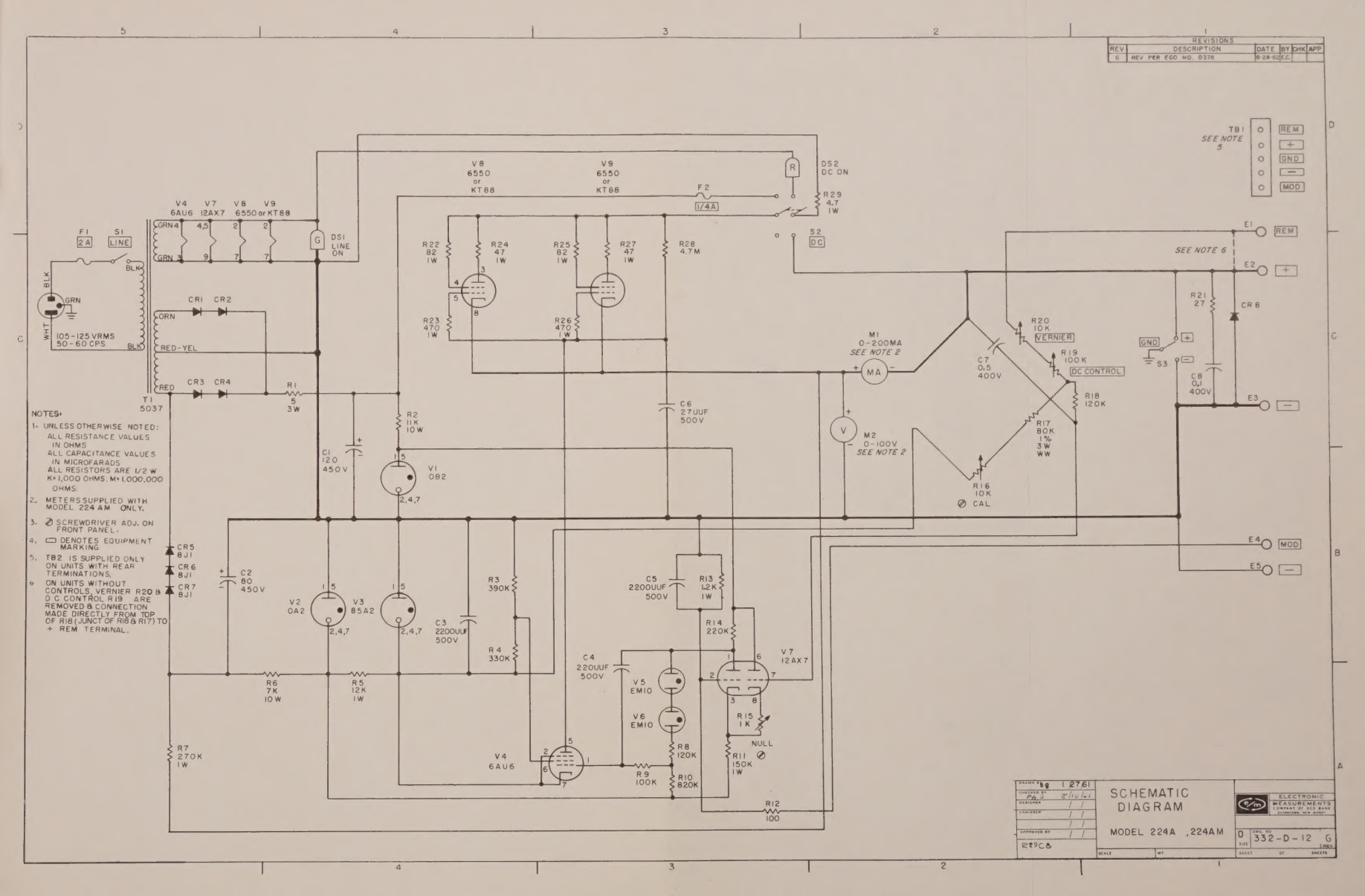
PARTS LIST ADDENDUM

220 volts, 50-60 cps input

*F1	Fuse, cartridge, 1A.	3AG1	Sightmaster
*S1	Same as for 115 volt input.		
T1	Transformer, power and reference		EMC

NOTES:

1. *ASTERISKED PARTS are recommended spares in quantity one per reference symbol, except fuses, which are three per reference symbol.
2. WHEN MAKING REPLACEMENTS: Part numbers are indicative of stock employed at the time of compilation of this list. Unless otherwise noted, and except for Electronic Measurements (E/M) numbers, "or equal" parts may be used for replacement. Electronic Measurements reserves the right to replace a part with an "or equal" part.
3. WHEN ORDERING PARTS FROM E/M: Include model and serial numbers of the instrument. Note carefully and include the letter suffix of any transformer number. In case of a discrepancy between a parts list number and the number actually printed on the part, employ the latter.
4. RECOMMENDED SPARES. When electrolytic capacitors are to be stored as spares for a year or more, request Technical Note 32.


REVISIONS
REV DESCRIPTION DATE BY CHK APP
G REV PER ECO NO. 0378 6-28-62 E.C.
TB1 SEE NOTE 5
REM
+
GND
−
MOD
E1 REM
SEE NOTE 6
E2 +
E3 −
E4 MOD
E5 −
V8 6550 or KT88
V9 6550 or KT88
R DS2 DC ON
F2 1/4A
R29 4.7 1W
S2 DC
V4 6AU6 V7 12AX7 V8 6550 or KT88 V9 KT88
F1 2A
S1 LINE
G DS1 LINE ON
BLK
GRN
WHT
105-125 VRMS 50-60 CPS
ORN
RED-YEL
RED
T1 5037
CR1 CR2
CR3 CR4
R1 5 3W
R22 82 1W
R24 47 1W
R25 82 1W
R27 47 1W
R28 4.7M
R23 470 1W
R26 470 1W
M1 0-200MA SEE NOTE 2
MA
M2 0-100V SEE NOTE 2
V
C7 0.5 400V
R20 10K VERNIER
R19 100K DC CONTROL
R18 120K
R17 80K 1% 3W WW
R16 10K CAL
GND
S3
R21 27
CR8
C8 0.1 400V
C6 27UUF 500V
R2 11K 10W
C1 120 450V
V1 0B2
2,4,7
CR5 8J1
CR6 8J1
CR7 8J1
C2 80 450V
V2 0A2
V3 6SA2
C3 2200UUF 500V
R3 390K
R4 330K
C5 2200UUF 500V
R13 1.2K 1W
R14 220K
C4 220UUF 500V
V5 EM10
V6 EM10
V7 12AX7
R15 1K NULL
R8 120K
R11 150K 1W
R9 100K
R10 820K
R6 7K 10W
R5 12K 1W
R7 270K 1W
V4 6AU6
R12 100
NOTES:
1. UNLESS OTHERWISE NOTED: ALL RESISTANCE VALUES IN OHMS. ALL CAPACITANCE VALUES IN MICROFARADS. ALL RESISTORS ARE 1/2 W. K=1,000 OHMS. M=1,000,000 OHMS.
2. METERS SUPPLIED WITH MODEL 224 AM ONLY.
3. SCREWDRIVER ADJ. ON FRONT PANEL.
4. DENOTES EQUIPMENT MARKING
5. TB2 IS SUPPLIED ONLY ON UNITS WITH REAR TERMINATIONS.
6. ON UNITS WITHOUT CONTROLS, VERNIER R20 & D.C CONTROL R19 ARE REMOVED & CONNECTION MADE DIRECTLY FROM TOP OF R18 (JUNCT OF R18 & R17) TO + REM TERMINAL.
SCHEMATIC DIAGRAM
MODEL 224A, 224AM
ELECTRONIC MEASUREMENTS
D 332-D-12 G

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